Senna siamea Lamk. (synonyms: Cassia siamea Lamk., C. florida Vahl.; Senna sumatrana, Roxb.) is a nonnitrogen-fixing leguminous tree in the subfamily Caesalpinoideae of the family Leguminosae. It has been widely planted in many Southeast Asian countries for erosion control, windbreaks, shelterbelts, fuelwood, and polewood. It is a good ornamental tree for planting along roadsides, and it is also used in alley cropping, intercropping, and hedgerows. It is planted as a shade tree in cocoa, coffee, and tea plantations. It is commonly called Thailand shower, minjiri, or kassod and has many regional names (Brandis 1906, F/FRED 1994).

**Botany**
*Senna siamea* is a medium sized evergreen tree attaining 5 m height in and conditions (F/FRED 1994). It rarely exceeds 20 m height and 50 cm diameter at breast height (Jensen 1995). It has a dense, evergreen, irregular, spreading crown, a crooked stem, and smooth, grayish bark that is slightly fissured longitudinally. Its young branches have fine hairs. The leaves are pinnately compound with an even leaf arrangement of 7-10 pairs of ovate-oblong leaflets 7-8 cm long and 1-2 cm wide. Its flowers are yellow, borne in large terminal panicles that are often 30 cm long. The flowering period is long, and flowers may often be found at various seasons (Troup 1921). The fruit is a flat pod 15-25 cm long, thickened at both sutures, containing many seeds (Gutteridge 1997).

**Ecology**
*Senna siamea* grows well in many environments, but it grows particularly well in lowland tropics having mean annual rainfall of 500-2800 mm (optimum about 1000 mm), mean minimum temperature of 20°C, and mean maximum temperature of 31°C. In semiarid environments with mean annual rainfall of 500-700 mm it will grow only where its roots have access to groundwater and where the dry season does not exceed 4-6 months. Best growth occurs in deep, well drained, rich soils with pH 5.5-7.5. It tolerates well drained lateritic or limestone soils and moderately acid soils (pH 5.0). It is susceptible to cold and frost and generally does not grow well above 1300 in. It requires full sun (Gutteridge 1997, Davidson 1985).

**Distribution**
*Senna siamea* is native to South and Southeast Asia, from Thailand and Myanmar (Brandis 1906, Gamble 1922) to Malaysia, India, Sri Lanka, and Bangladesh (Khan and Alam 1996). It has been cultivated worldwide and is naturalized in many locations (Gutteridge 1997).

**Uses**
**Wood.** *Senna siamea* wood is used for furniture, poles, small timber, and fuelwood. It is hard, with specific gravity of 0.6-0.8. The sapwood is whitish, and the heartwood is dark brown to nearly black, with stripes of dark and light (Gamble 1922). The fuelwood and charcoal are highly regarded (calorific value of 4500-4600 Kcal/kg), but the wood produces a lot of smoke (F/FRED 1994).

**Other uses.** *Senna siamea* is used in intercropping systems, windbreaks, and shelterbelts. It is also used as a shade tree in cocoa, coffee, and tea plantations (F/FRED 1994). The tree produces an extensive root system in the upper layer of the soil and, in intercropping systems, can aggressively compete for nutrients and water (Gutteridge 1997). The leaves and seeds can be eaten by ruminants (Sahni 1981) but are toxic to non ruminants such as pigs and poultry. The young leaves and flowers are used in curry dishes. The species is also used for the production of honey and tannins.

Written by Dr. Mohammed Kamal Hossain, Associate Professor, Institute of Forestry and Environmental Sciences, Chittagong University, Chittagong 4331, Bangladesh.
Silviculture

Propagation. *Senna siamea* is usually propagated by seed, and plantations are often established by direct seeding (Gutteridge 1997). Mature pods should be collected from the tree when they turn brown, but mature, half opened pods may be collected from beneath the trees (Siddiqi and Ali 1994). After collection, the pods should be dried in the sun for a few days. The seeds are small and greenish-brown, and there are about 37,000-43,000 seeds per kilogram (Katoch 1992, Hor 1993). Clean seeds can be stored in air-tight containers at room temperature for years with little loss of viability. Fresh seeds generally do not need any treatment, but soaking them in cold water for 12 hours accelerates germination (Siddiqi and Ali 1994). Germination is complete within 7-20 days and germination percentage typically exceeds 70 percent. Katoch (1992) dipped the seeds in hot water for 1 minute before soaking them in cold water for 24 hours, and obtained 98 percent germination in 28 days.

In the nursery, seed may be sown in containers, or nursery beds and trays and transplanted to containers after germination. Polybags 10 x 15 cm are widely used in Bangladesh for raising seedlings. Well drained sandy-loam soil (preferably forest topsoil) mixed with manure or well-decomposed compost in a ratio of 3:1 is recommended for nursery use. In addition, 500 g each of triple superphosphate and muriate of potash may be added to every cubic meter of nursery soil. In each polybag, 2-3 seeds should be sown at a depth of 0.5-1.0 cm and covered with a thin layer of sand. Seedling growth is favored by loose soil, sufficient soil moisture, full sunlight, and absence of weeds.

Seedlings are kept in the nursery for 12-14 weeks or until they have attained a height of 25-30 cm. Root pruning and hardening off the seedlings before transplanting is beneficial. Containerized seedlings generally have better survival than direct-sown seedlings, particularly under heavy weed competition. *Senna siamea* can also be planted as stumps (Evans 1982).

Management. Plantations can be managed by coppicing, lopping, or pollarding (F/FRED 1994). Fuelwood, the recommended spacing is 1 x 1 in to 1 x 3 in, with the first harvest in 5-7 years. In hedges for alley cropping or shelterbelts, spacing between plants within rows should be 25-50 cm. For mulch or leaf production, the first cut may be 12-18 months after sowing, followed by 3-4 cuts per year thereafter (Gutteridge 1997). A small dose of NPK fertilizer in the first year helps the seedlings' initial growth; the fertilizer level varies with the site quality. In the field, weed control is essential during the first 1-2 years. The first weeding should be 2 months after plantation establishment, or depending on the intensity of the weed growth. Weeding of noxious plants such as climbers, creepers, and vines is recommended, but less harmful weeds may be left in the field.

On good sites, *S. siamea* can grow to a height of 8 in and a root collar diameter of 20 cm in 40 months. In a tree trial in southern Sumatra, the species produced 1200 g of leaves per plant per year. Total yield of wood for timber, poles, and fuelwood may reach 10-15 m³/ha/year (Gutteridge 1997).

Symbiosis

*Senna siamea* does not nodulate or fix nitrogen through symbiosis with *Rhizobium* bacteria.

Limitations

No significant pest or disease damage has been recorded, but minor damage can be caused by the wood rot *Ganoderma lucidum* (Khan and Alam 1996). Insects that damage seed include *Caryedon lineaticollis* and *Bruchidius maculatipes*. Seed-borne fungi reported in Thailand include *Aspergillus niger* and *Curvularia pallescens* (Hor 1993). The fungus *Phaeolus manihotis* occasionally causes damage to the root system (Gutteridge 1997).

Research Needs

Studies are needed to evaluate *Senna siamea* for timber production and to evaluate its potential as a fodder crop for ruminants.

References


Sesbania grandiflora: NFT For Beauty, Food, Fodder And Soil Improvement

Sesbania grandiflora is a tree that grows rapidly, provides light shade, and is often grown as an ornamental. This soft-wooded tree's leaves are used as fodder and its flowers as food. Grandiflora is planted in gardens for its intercropping compatibility and soil improving properties.

Botany

Sesbania grandiflora (L.) Poir. is a tree that grows to 8-10 m in height. The pink-red or white flowers of this papilionaceous (pea-like flowered) legume are unusually large (5-10 cm in length and about 3 cm wide before opening); this novelty may be the principal reason for grandiflora having been distributed by man throughout the tropics and subtropics. Within its genus, S. grandiflora is a member of the subgenus Agati, and it is thus more closely related to the unusual littoral sesbanias of Pacific islands than to the more typical sesbanias of subgenus Sesbania, such as the perennial S. sesban and the annual sesbanias grown for green manure (such as S. canabina).

Grandiflora's pinnate leaves may be 30 cm long, with 12-20 pairs of oblong, rounded leaflets averaging 3-4 cm long and about 1 cm wide. The leaves are borne at the terminals of branches, and the canopy is open, with a thin crown which produces light shade. Its racemes bear 2-3 flowers. The pods are usually 30-50 cm long by about 8 mm wide. The seeds are tan to red-brown, 6-8 x 3-5 mm, 14-20 weighing 1 g. The trunk may reach 25 cm diameter at breast height. Grandiflora may live 20 years or more.

Grandiflora is very closely related to the endemic Australian species, S. formosa. This relationship supports the supposition that grandiflora may have originated in Indonesia. S. formosa bears white flowers and is often indistinguishable from grandiflora to the casual observer. The two species appear to have similar growth habits and adaptivity, and it is possible that S. formosa also can be used for the purposes described here for grandiflora.

Distribution

Grandiflora is found in cultivation throughout the tropics and subtropics.

Ecology

Because wild populations of grandiflora are unknown, its natural habitat is uncertain. Grandiflora is grown most successfully in the lowland tropics (below 1000 m elevation) and warm, frost-free subtropics. It can be grown in regions with as little as 800 mm rainfall or as much as 2000-4000 mm. It seems to prefer a bimodal rainfall distribution, growing rapidly during wet seasons but capable of withstanding prolonged dry seasons of up to nine months. Grandiflora is tolerant of soil salinity and waterlogging, and withstands occasional short periods of flooding. It is well adapted to heavy clay soils.

This issue was prepared by Dale O. Evans, Research Associate, Department of Horticulture, University of Hawaii, 3190 Maili Way, Honolulu, Hawaii 96822, USA.
Uses
Fodder, food, and soil improvement are the principal uses for grandiflora.

Fodder. Grandiflora is valued as a fodder in many regions. In south central Lombok, Indonesia, grandiflora grown around rice paddy bunds provides up to 70 percent of the diets of cattle and goats during the annual eight-month dry season (Mudahan Hazdi, personal communication). The leaves contain as much as 25-30 percent crude protein. Although ruminants readily consume grandiflora fodder, and its digestibility is high, some feeding studies have indicated that antinutritional factors are present. Until further research provides clear guidelines, caution should be used in feeding S. grandiflora to ruminants and other animals, and restricting feeding to less than 30 percent of dry matter intake is suggested. Grandiflora leaf is toxic to chickens and should not be fed to them or other monogastric animals.

Soil improvement. Grandiflora is often maintained in gardens and around crop fields for its contribution of nitrogen. The light shade cast by its canopy does not block much light, allowing the growth of companion plants. Falling leaflets and flowers recycle nutrients to the ground. Seedlings grow rapidly enough that they have been used similarly to annual green manure crops. For example, grown around paddy bunds for incorporation before planting the subsequent rice crop.

Wood. The wood is rather light and not ideal for firewood or pulping; the bark is thick and corky and is a further detriment to either of these uses. The trunks may be used as poles for temporary shelters and sheds, but they may not last very long due to rots and insect infestation.

Food. Leaves, seed pods, and flowers of grandiflora are prepared as food. The young, tender pods are cooked similarly to other green beans. In South Asia the young leaves are chopped and sautéed, perhaps with spices, onion, or coconut milk. In the Philippines, unopened white flowers are a common vegetable, steamed or cooked in soups and stews after the stamen and calyx have been removed. Selection of white-flowered varieties that flower profusely has resulted from this use in the Philippines.

Other uses. Grandiflora has been used to shade nurseries and some crops, such as turmeric, as support for climbing crops such as pepper and betel vine, and as an element of windbreaks. The leaves of the tree have various uses in the herbal medical lore of certain regions.

Culture and Management. Grandiflora is grown from seed, which may be planted without scarification. Stored seeds lose viability within a year or two. Seeds may be direct-sown or transplanted from nurseries; bare-rooted transplants are usually successful. Seedling growth of grandiflora may be very rapid. Under harsh conditions or neglect, however, seedling survival may be poor. The leaf canopy is open and casts only light shade, hence its popularity in gardens.

Grandiflora cannot be coppiced or pollarded. Harvesting leaves for fodder must be done selectively, to avoid complete defoliation, and cannot be done more than a few times per year. More intensive harvesting, such as managing as a hedgerow, reduces the life of the tree. For example, cutting at 1 m high five times a year can result in tree mortality. Because grandiflora establishes so rapidly, frequent replanting is a management option if heavy harvesting results in tree decline.

Where flowers and pods are harvested for consumption as vegetables, the structure of the tree is shaped by pruning so that the canopy remains low, within reach for convenient harvesting.

Symbiosis
The rhizobia strains that nodulate sesbanias are somewhat specialized and may not be present where sesbanias have not been grown previously. Test plantings should be done to see if infective rhizobia are present in the soil, or if use of a rhizobia seed inoculant at planting will be necessary.

Limitations
Grandiflora's soft wood is susceptible to damage by insects. Fodder cuttings cannot be severe. Seed recovery may be limited by pod pests. Seed viability declines after one year.

References
Sesbania sesban: Widely Distribute Multipurpose NFT

*Sesbania sesban* is a many-branched, soft-wooded tree that grows rapidly and is useful for fodder and green manure. This species has long been used for browse and soil improvement in India and Africa. Recent interest in multipurpose, nitrogen fixing trees has caused it to be collected, studied, and recommended for fodder "banks" and alley cropping.

**Botany**

*Sesbania sesban* (L.) Merrill is a tree that grows to 8 m height. This papilionaceous (pea-like flowered) legume bears racemes of 4-20 yellow flowers that may be lightly to heavily streaked with purple. Sesbans have pinnate leaves with 20-50 opposite pinnules on a rachis 3-12 cm long. The leaf rachis and the underside of the leaflets are often pubescent. The pods are usually 10-20 cm long and contain up to 40 seeds that are brown, or dark green mottled with black. The trees usually have one main stem, but they may develop many side branches if they have space. Sesban's many branches often give the tree a shrubby appearance. It tends to have a spreading habit due to its wide branching angle (as wide as 45-60°).

Within its genus, sesban is classified in the subgenus Sesbania, and thus is more closely related to the annual sesbans grown for green manure (such as *S. cannabina*) than to the other well known perennial species of the genus, *S. grandiflora*, which is in the subgenus Agati (Evans 1990). Several varieties of sesban are recognized. The botanical distinctions among sesbanias are often difficult for non-botanists to see, and sometimes sesban is confused with the annual types of sesbania.

**Ecology**

Sesban occurs naturally in semi-arid to subhumid areas with 500-2000 mm of rainfall. It seems to do well under bimodal rainfall distributions, where heavy rains and even flooded conditions are followed by a progressively drier season. It grows from sea level to 2000 m elevation, but the upper limit is uncertain. It does not tolerate frost. It is uniquely well adapted to periodic waterlogging and flooding. Soil alkalinity and salinity is tolerated to a considerable degree. Some research suggests that certain sesban types may grow well on acidic soils.

Sesbans are relatively short-lived, and under intensive browsing or cutting management will not last more than 3-5 years. Their rapid seedling growth is conducive to short-term fallows and to replanting if management should reduce growth vigor.

**Distribution**

Sesban is found throughout the tropical and subtropical parts of Africa, Asia, and Australia. It is not widely distributed in the Americas. Africa is its center of diversity, and sesban probably originated there; its former name is *S. aegyptiaca*. From northeastern Africa, *S. sesban* var. *sesban* and its variants were spread across southern Asia, possibly by man. Within Africa, *S. sesban* var. *nubica* is the type most commonly found, and there are several sesbanias closely related to sesban, such as *S. goetzei* and *S. cinerascens* (Gillett 1963).


**Uses**

Sesban is mostly used as fodder and for soil improvement, its wood is used only to a lesser extent (Evans and Macklin 1990).
Fodder. The leaves and tender branches of sesban are high in protein (20-25% crude protein) and have high digestibility when consumed by ruminants, such as cattle and goats. Anti-nutritional factors are suspected to be present in sesban fodder. Feeding sesbania foders to monogastric animals (such as chickens, rabbits, and pigs) is not recommended.

Reports of feeding sesban to ruminants conflict. Trials in Australia feeding sesban to heifers showed live weight gains, but trials with young goats in Samoa found a lack of weight gain. Until further research provides clear guidelines, caution should be used in feeding ruminants with sesban fodder at more than 10-20 percent of diet.

Soil improvement. Sesban establishes quickly and grows rapidly. In Africa it is often allowed to grow scattered throughout annual crop fields for the nitrogen it provides. It has been used in experimental alley cropping systems to provide mulch and greenleaf manure to intercrops. Sesbas can be somewhat shallow rooted, and may compete with adjacent crops.

Wood. Sesban's wood is light in weight compared to the woods of Calliandra and Leucaena, but it is often harvested for firewood in Africa and India. It has been used in India to make charcoal. The wood is not durable and should not be considered for timber use. The branches have been used as poles in temporary structures such as sheds and mud daub huts.

Because sesban grows so rapidly, it has potential for pulpwood production. Plantings at about 10,000 trees/ha have produced 15-20 tons of woody biomass (dry weight) in one year.

Food. Flowers of sesban are known to be added to stews and omelets in some regions, perhaps mainly as a decorative element.

Other uses. Various medicinal uses for sesban have been recorded in Africa and Asia (Evans and Rotar 1987, Evans and Macklin 1990). The leaves and flowers are used in medicinal poultices and teas, which are said to have the effect of astrigence, or contraction of body tissues. Bark exudates from sesban produce a gum of medium commercial quality.

Culture and Management

Sesban is generally propagated from seed, although it has been rooted from cuttings, and research has revealed that it can be established by tissue culture. Seed scarification usually improves germination. Recommended hot water scarification is a 30-second dip in water heated to just below boiling. Seed weights range from 55-80 per gram for S. sesban var. sesban to 80-130 per gram for var. mubica.

Plants grown for fodder production can be placed as close as 30-50 cm apart in rows 1 m apart. Appropriate distances between rows in alley cropping will depend on the variety grown, the ecology of the site, and intensity of management.

Experimental fodder cutting trials have yielded 20 tons/ha dry matter in the first year. However, sesban cannot be managed with the severity that Leucaena tolerates in fodder and wood biomass production systems. If sesban is cut too low (below 50-100 cm) or too frequent (more than 4-6 cuttings per year) death of the plants can result. When cutting sesban it is recommended to leave 10-25% of the foliage on the plants.

In some climates, such as the highlands of Kenya, sesban may have a sparse canopy and weed competition can be a problem. This characteristic makes sesban a good intercrop. Sesban has been grown with the fodder grass Brachiaria mutica in India, and to provide shade to young coffee plants in Kenya. In climates where sesban grows more vigorously, weeds are shaded out and companion plants may be adversely affected; this type of growth has been observed in Hawaii and Jamaica (Roshetko et al. 1991).

Symbiosis

The rhizobia strains that nodulate sesbanias are somewhat specialized and may not be present where sesbanias have not been grown previously. Test plantings should be done to see if effective rhizobia are present in the soil. If not, use of a rhizobia inoculant at planting will be necessary.

Limitations

Sesban is not a tree for timber or reforestation in the ordinary sense of forestry or silviculture. Because the range of its ecological adaptability is not yet well known, test plantings should be done before large-scale plantings are planned. Sesban has been observed occasionally to die back under cutting management; fungal infection may be the cause. Leaf-feeding insects sometimes limit production. Seed chalcids can reduce seed recovery.

References


Financial support for this NFT Highlight was provided by the Rockefeller Brothers Fund through the Southeast Asia NGO Support Program.
Ziziphus mauritiana: A Valuable Tree for Arid and Semi-arid Lands

The leaves are alternate, ovate or oblong elliptic, with 3 veins at the base, and are usually about 2.5 to 3.2 cm long and 1.8 to 3.8 cm wide. The flowers are yellow, 5-petalled and are usually in twos and threes in the leaf axils. This quick growing tree starts producing fruits within three years. It will not set fruit by self-pollination. Fruits vary in shape and size. They can be round, oval or oblong; large, medium or small. Most are round to oval. Size can be as small as 1.8 to 2.5 cm for fruit from wild trees or as large as 5 cm (plum sized) from improved cultivars. Ber fruits are first green, turning yellow as they ripen. The ripe fruit is sweet and sour in taste. Both flesh texture and taste are reminiscent of apples.

Ecology
Commercial cultivation of ber usually extends up to 1,000 m. Beyond this elevation trees do not perform well and cultivation becomes less economical. This species is able to survive temperatures as high as 50°C. In India trees survive minimum shade temperatures of 7°C to 13°C. However, this hardy fruit tree does not tolerate frost well. Native to the tropical and sub-tropical regions, ber can grow where annual rainfall ranges from 125 to 2,225 mm, but is more widespread in areas with an annual rainfall of 300 to 500 mm. It is known for its ability to withstand adverse conditions, such as salinity, drought and waterlogging. Studies report that this species flourishes in alkaline soils with a pH as high as 9.2. However, deep sandy loam to loamy soils with neutral or slightly alkaline pH are considered optimum for growth.

Distribution
Early studies indicate that the center of origin of ber is Central Asia. This species is indigenous to North Africa; from Afghanistan through north India to southern China; Malaysia; and Queensland in Australia. However, ber is now widely distributed and has become naturalized in tropical Africa, Iran, Syria, Sri Lanka, Burma, Barbados, Jamaica, Guadeloupe and Martinique, and parts of the Mediterranean.

Uses
Fruits. Ber fruits are very nutritious and are usually eaten fresh. Relatively unknown, this fruit is a rich source of vitamin C. It is second only to guava and much higher than citrus or apples. It contains 20 to 30% sugar, up to 2.5% protein and 12.8% carbohydrates. Fruits are also eaten in other forms.

Written by Susan Kaaria, University of Minnesota, Forest Resources Department., 1530 Cleveland Ave. N., St Paul, MN 55108-1027 USA

159
such as dried, candied, pickled, as juice, or as butter. In Malawi, dried fruit is used to make a potent distilled alcoholic beverage. Yields of 80 to 130 kg/tree/year have been reported in Africa (von Maydell 1986).

Fodder. In parts of India and north Africa, the leaves of ber are used as nutritious fodder for sheep and goats. Analysis of the chemicals constituents on a dry weight basis indicate the leaves contain 15.4% crude protein, 15.8% crude fiber, 6.7% total minerals, and 16.8% starch. In India, the leaves are also gathered as food for silkworms (Gupta 1993).

Wood. Ber timber is hard—with a specific gravity of 0.93—strong, fine-grained and reddish in color. It is most often used to make agricultural implements. The branches are used as framework in house construction. Ber makes good charcoal with a heat content of almost 4,900 kcal per kg. In addition, this species is used as firewood in many areas.

Other uses. This thorny tree makes good live fencing and is an excellent agroforestry tree to use in hedges. In India, ber trees are a host for the lac insects Kerria lacca, which are found on the leaves and makes an orange-red resinous substance. The purified resin makes a shellac used to produce sealing wax and vanish. High quality ber shellac is used in fine lacquer work.

Silviculture

Natural reproduction is through seed, stump, root suckers and coppice. Many existing silvicultural practices were developed in India, where domestication work began as early as the 1950’s.

Propagation. Scientists in India have standardized propagation techniques for ber establishment. Budding is the easiest method of vegetative propagation used for improved cultivars. Different types of budding techniques have been utilized with ring-budding and shield-budding being the most successful. Wild varieties of ber are usually used as the rootstock. The most common being Z. rotundifolia in India and Z. spina-christi in Africa. Seedlings to be used as rootstock can be raised from seed. Several studies indicate that germination can be improved by soaking seeds in sulfuric acid. Germination time can also be shortened to 7 days by carefully cracking the endocarp. Ber seedlings do not tolerate transplanting, therefore the best alternatives are to sow the seeds directly in the field or to use polyethylene tubes placed in the nursery bed. Seedlings are ready for budding in 3 to 4 months. In addition, seedlings from the wild cultivars can be converted into improved cultivars by top-working and grafting. Nurseries are used for large scale seedling multiplication and graft production.

Spacing and fertilizer requirements. For orchard establishment recommended spacing is 7 x 7 m or 8 x 8 m. The wider spacing is preferred in areas with high rainfall where canopy development is vigorous.

Many studies in India recommend the application of both farmyard manure and commercial fertilizers to maximum production. In Africa, the recommended fertilizer application is 20 to 120 kg N, 100 to 120 kg P, and 20 to 50 kg K per hectare. Fruit production begins in the 4th year with full production in the 10th to 12th year (von Maydell 1986).

Training and pruning. It is essential to train ber trees during the first 2 to 3 years to build a strong frame. Otherwise, these trees have a tendency to grow horizontally and downwards. If untrained, trees develop into a spreading bushy form, with long slender branches. Yearly pruning is also important because fruits are produced on current season’s growth. Regular pruning induces sufficient new growth to produce a good fruit crop annually. Removing 25% of the growth is usually sufficient. Pruning should occur when plants are dormant.

Limitations

Pests and diseases. The most serious pest of ber are the fruit flies, Carpomyia vesuviana and C. incompleta, which attack the fruits at the "ped" stage. Susceptibility generally differs by cultivar. Control of the pests can be attained by regular spraying of insecticides. Powdery mildew is the most important disease and results in premature defoliation and fruit drop. The disease can be effectively controlled by using chemicals.

Principal references


Improving Markets for Farm Forestry Products

Traditionally, forestry development programs have focused on improving production and not on the products and their marketing. These programs have successfully raised production levels, but have not been successful in helping farmers meet marketing needs. Producers often lack understanding of basic marketing fundamentals and how best to market their products. To find and penetrate markets effectively, one must have knowledge of critical market information such as supply and demand, and other factors affecting markets for products (Sullivan et al. 1991).

Many forest farmers are not aware of markets available and the means of getting their products to these markets. The result is that farmers often receive lower prices, are not aware of new or different market opportunities, or have little information to use for planning. Traders visiting local areas are often the only outlets. Producers do not know how to price their products, or determine demand, especially in new or distant markets. This lack of knowledge makes producers ineffective when dealing with middlemen.

Increased availability of market information will help producers strengthen their marketing skills and get higher prices, and lead to increased awareness of important marketing practices.

The Basics
Marketing involves the many aspects of moving a product from the farm to market (see basic marketing text such as Kotler and Armstrong 1996). Prior to planting the markets for all potential products should be discussed. This may be difficult for products not ready for market until several years in the future, such as timber or fruits.

Producers should understand how to promote their products in the market. They should know how to store products to ensure they do not lose value. Sorting by quality or grade, and packaging products together with similar characteristics will help the product sell quickly and for a higher price. Proper harvest, storage, and transport will help assure that the maximum amount of product reaches market and that the farmer receives the maximum possible return.

Efforts to increase production of agroforestry products should be balanced and should look at all levels of production and handling of products. Producers often suffer from decreased revenues when marketing needs are not addressed.

Increasing markets through improving market information
One key way to improve markets for local producers is to increase access to market information. This can be accomplished by organizing a locally operated market information collection system. The cost of collecting information can be minimal and the importance of marketing reinforced if the producers collect information about the market while on regular marketing or buying trips.

Local farmers need to identify ways to improve marketing of their existing products and plan for future products. A market information checklist included here (see outline in box) is a good place to start. It was developed in the Philippines and tested in several Asian countries (Hammett 1994), and should help producers obtain the information they need to increase returns on current products and help plan for future crops.

First, an assessment of local market information needs, and the identification and evaluation of existing market information sources should be completed. A lack of local marketing expertise and market information for agroforestry products can make this task challenging. Most farmers produce only at the subsistence level; what little they produce in excess of their own needs is sold locally by the roadside or in nearby weekly markets. When surplus production occurs, farmers usually sell to traders or middlemen and do not have the capability to market products in other markets.

Market information should not only provide farmers with support for their marketing efforts, but help them optimize the selection of and mixture of forest and agriculture crops. Increased market information results in increased value for products, more efficient marketing, and improved production levels where further local processing may become feasible.

Guidelines for improved access to market information
The guidelines include steps needed to collect, assemble, and disseminate market information at the local level. The suggested sequence of these steps can be adjusted for other products and sites, and may be adapted to suit evolving farmer needs.
A market information system checklist

1. Assess local market information needs
   - Identify and organize a group of producers
   - Set goals for the group to improve marketing

2. Analyze the local situation
   - Determine what types of market information are needed
   - Select products appropriate for marketing promotion
   - Assess available market information (price, quality, volume, seasonal)
   - Determine other marketing needs of the group

3. Establish market information system
   - Develop system by which information is collected and disseminated
   - Delegate collection and dissemination duties
   - Keep simple records

4. Develop framework for sustaining the system
   - Determine the support needed to continue the system
   - Locate sources of support needed
   - Seek support from programs or activities of local organizations

5. Keep the program focused on local needs
   - Include community input on a continual basis
   - Ensure that the system will suit the changing needs of the producers
   - Allow for the expansion of the system

It is important to identify existing markets for local products by interviewing key informants in local markets (at farm gate or roadside) within a village or locality where friends or casual acquaintances are sellers and buyers; regional markets (nearby towns or city markets) in which local products are sold; and nearby weekly markets (identify days of these markets). Major traders or large scale industrial buyers in the region can also be key sources of information.

Individual farmers may wish to join a local farmer’s association to collect marketing information. This increases their access to information and helps ensure that collection and dissemination processes are sustained. It is crucial that any existing (formal or informal) market information system be identified and used. Informal sources of market information, such as other farmers returning from selling their products, are also valuable. Presence of a central location for information dissemination and close proximity to potential markets are also important.

One should assess the type and frequency of information needed and the timing needed for market information. Long term production decisions will need historical market data (monthly, and/or yearly), predictive information, and less frequent reporting. For certain perishable products, daily (or hourly) fluctuations may determine the need for more frequent information. One can determine if daily, weekly, or fortnightly price information is necessary.

Appropriate channels of communication for local producers to learn about markets may include relevant producer associations. In Pakistan, a tree farmer association helps individual forest farmers market their products.

It is important to identify a mechanism by which a system can be sustained without outside support. Location of other sources of market information may help save local resources and make the system more sustainable. The potential for involvement and support by participating groups such as farmer associations or cooperatives should also be considered. It is also important to incorporate the needs of local farmers within an existing market information system. Such linkages will save valuable resources and help farmers easily expand the area and products not otherwise included.

Clear, simple records of all market information collected need to be kept. This information will be useful when planning future marketing or production activities. Local users’ ability to comprehend presented information will be an important indicator for determining appropriate dissemination techniques. It is important to select appropriate techniques to transmit information to the target users. This will include determining the appropriate media, such as blackboards posted at major intersections as was used in the Philippines (Hamnett 1994). Consideration must also be given to location of dissemination points so that the maximum number of users have access to the information.

It is helpful to determine the effects of any system on producers’ marketing activities. The system should be evaluated in such a manner that increased production and markets can be analyzed and understood by the farmers. Results of such an evaluation would also be useful to extension workers and program planners.

Observations

Developing a locally appropriate system to collect and disseminate market information can be implemented after modest commitment of resources and is suitable for many farm forestry products. Collaboration by farmers as a group and with input from other organizations is important—it saves small producers’ time and valuable resources.

Marketing needs to be flexible enough so that it can be adapted to changing needs of the market place. The testing of farm forestry products before they are produced or marketed is usually not possible. However, through increased knowledge of markets, important indications of product marketability can be gained before valuable resources are committed.

Training in marketing and planning is critical, but often missing from many programs. Exchange of new product ideas and information about markets among farmers will give indications of skills and knowledge needed.

Organizing and implementing a market information system is not complex and is feasible—even for small, local producers. In the Philippines, local farmers now train other farmers how to improve marketing and how to collect and use market information. An increased focus on marketing will make a difference, especially for small forest farmers needing increased incomes and better planning.

Selected References


A list of related marketing references is available from FACT-Net.
Section 2.

AIS Technologies and Species Factsheets
Agroforestry land-use technologies are nothing new in the Pacific Island region, or the world for that matter. In a loose sense, agroforestry began when Man first turned from a hunting and gathering lifestyle and took up plant culture. Though maybe not purposefully integrated, trees and farm crops have always occurred together in systems where subsistence was the primary farming objective.

Social trends and economic development forces of more recent times have placed a huge amount of importance on short-term product and thus profit maximization. Cash, rather than subsistence crops have been the focus of more advanced societies. Economic rationale tells the farmer to maximize production of the crop that gets him/her the most money at the market. Agroforestry system were often replaced with crop mono-culture where trees were seen to interfere with crop yield.

Today, many agree that the rapid agricultural conversion that went on during the "green revolution" was short-sighted indeed. Intensive mono-cropping systems, though perhaps more profitable for a time, are much more risky and costly in the long run. Risky because crop prices are always changing and pest infestations can destroy entire harvests. Costly because these intensive farming practices degrade most soils rapidly; and thus require expensive chemical and fertilizer inputs to sustain productivity.

The scattered and isolated nature of Pacific Island countries is a mixed blessing. The region, has been, excluded from most global trade activities and international market pressures. Most countries have not been driven to costly mistakes in attempting to maximize short-term export income. Multi-cropping agroforestry systems remain intact over much of the landscape.

The region is not without its problems. Arable land has never been in abundant supply. Growing population pressures and modern land ownership uncertainties make land scarcities increasingly apparent. The most common traditional agroforestry systems of the swidden variety, are no longer sustainable where a shortage of land forces farmers to reduce fallow periods. Root crops, staples in most cultures, require that the soil be disturbed twice in a single rotation. Shortened fallows do not allow soils to recover. They quickly lose their productive potential and become highly erodible.

Traditional agroforestry systems must be improved so as to increase subsistence and market produce from limited land areas over time. In more modern, more intensive agroforestry systems, trees are not just tolerated or passively allowed to regenerate during falls. They are planted, arranged, managed, and harvested alongside agricultural crops and/or farm animals in a way that optimizes overall farm productivity in the short and long term. Trees are used to create a more favorable and sustainable environment for crop and/or animal production while providing additional products themselves.

**Why are Agroforestry Systems more Productive?**

They use limited resources more efficiently

- **SUN:** Multi-storied cropping systems absorb sunlight at all levels.
- **SOIL NUTRIENTS:** Deep tree roots take up soil nutrients and moisture that are out of reach of root crops.
- **WATER:** Trees shelter crops and soil surfaces from drying winds and intense sun. Tree-leaf mulch retains moisture in upper soil layers.
- **LAND:** Trees serve to continuously sustain rather than periodically rebuild soils. Fallow requirements are reduced, leaving more land in production at any one time.

They provide a more favorable environment for sustained cropping:

- **SHADE:** Filtered shade keeps topsoil cool, increasing beneficial soil microbe activity and reducing soil water loss.
- **WIND PROTECTION:** Trees protect the soil and crops from damaging, erosive, and drying winds.
- **SOIL ANCHORING:** Tree roots bind soil, preventing down-slope erosion during rains.
• **SOIL BUILDING/MAINTENANCE:** Tree leaf litter becomes organic humus that builds good soil structure. The stronger soil is more resistant to erosion and more able to absorb/hold water.

• **NUTRIENT CYCLING:** Trees draw nutrients from below crop root reach and then release them on the soil surface as leaves fall or branches are pruned.

• **HABITAT DIVERSITY:** Trees provide habitats for animals and birds that eat crop pests and insects.

They provide a more continuous flow of more products over time.

• **SHORT-TERM PRODUCTS:** Root and grain crops, tree nuts and fruits, fuelwood, posts, animal fodder, medicines, and livestock.

• **LONG-TERM PRODUCTS:** Valuable construction timber, larger fuelwood, and other wood products such as pulp and veneer.

**Why is Agroforestry so Necessary in the Pacific?**

• **TRADE WINDS:** Crops and soils need protection from wind damage, drying, and erosion.

• **ROOT-CROP CULTIVATION:** Methods expose and disturb soil twice in a rotation.

• **INTENSE RAINS:** On sloping terrain, frequent, intense rains wash soil away rapidly if it is disturbed and unprotected.

• **VOLCANIC SOILS:** Soils derived from volcanic rock and ash are commonly acidic and thus more subject to nutrient loss/leaching.

• **LAND SCARCITY:** Arable land is the most scarce and thus valuable natural resource.

Agroforestry is arguably a more sustainable and optimal way of farming in most resource-limited environments. This seems to be especially true in the Pacific, where growing and developing populations are confined to relatively small and scattered areas.

Successful agroforestry though, requires careful planning and usually more labor Trees and crops must be arranged and managed properly if overall productivity is to be increased and sustained. Left unmanaged, trees can out-compete crops, and reduce yields.

Pacific Island farmers appreciate the worth and function of trees in agricultural systems. They did not traditionally, however, manipulate and manage the tree component to the degree that most modern agroforestry practices require. They must be convinced that the products and benefits will justify their added time and labor inputs.

The active promotion of agroforestry in the Pacific, through information transfer, demonstration, and on-farm research, is without question a worthwhile and timely task.
Root-crops, primarily taro, sweet potato, and cassava, are important subsistence and market foods in most Pacific Island cultures. Traditional upland root-crop cultivation included lengthy soil restoring fallows between short croppings. After just 2 to 3 years of root-crop production, lands were typically left to rest for 10 to 15 years. Farmers have always recognized that the planting and harvesting of root crops disturbs soils more than does the farming of above-ground crops. Root crops must be dug in and dug out.

Unfortunately, modern population pressures and land-ownership uncertainties are creating situations of land scarcity that make long fallows infeasible for most. The soil degradation resulting from shortened fallows is affecting productivity and increasing dependencies on food imports such as rice and flour in many areas.

Hedgerow intercropping (HI), the practice of farming annual crops in the spaces or 'alleys' between rows of multipurpose trees is a promising alternative to the traditional fallow system. Trees planted and managed in hedgerows provide the same products and services as those that were allowed to grow during traditional fallow periods. Trees cycle nutrients from deeper in the soil profile by shedding organic matter on the surface as leafy and woody litter or 'green manure'. Litter rebuilds a soil’s structure making it less erodible and more able to absorb and hold water. Hedgerows also yield other products such as fuelwood and fodder. They create a more favorable micro-climate for crops by shielding them from drying winds. Hedges planted on slopes, also anchor soil and form terraces, preventing the loss of precious topsoil by heavy rains and the overland flow of water.

Traditional systems combined trees with crops on the same piece of land in a time sequence. Hedgerow intercropping; combines trees with annual crops on the same piece of land at the same time. The tree and crop components are managed so as to be complimentary rather than competitive. The successful HI system maximizes the product per unit of land over time. To accomplish this, competition between the crops in the alleys and the trees in the rows must be minimized. This requires the orderly spatial arrangement and rather intensive management of the tree component. It could be said that traditional systems require a large land input whereas HI systems require more labor input. Where land is more scarce than labor, this agroforestry practice makes good sense.

Hedgerow intercropping; does not necessarily eliminate the fallow requirement. Because the tree component of the HI system is kept on the land during crop production, one could say that it performs a "semi-fallow" function continuously. This means that cropping cycles can be lengthened and fallows shortened without degrading the soil and reducing system productivity over time.

The trees recommended for these systems are chosen for their multipurpose/multiproduct characteristics. They provide soil-improving services, are fast-growing, and produce a number of useful products.

In short, the primary benefit of HI over traditional systems, is a more continuous, more sustainable flow of both tree and food products from one piece of land through time.
I. TREE SPECIES SELECTION

HI trees provide desired products/services while competing as little as possible with neighboring crops. Characteristics of good HI trees are:

- **Rapid growth and biomass production**: More leafy biomass and small branch production means more litter/mulch accumulation, more fodder, and/or more fuelwood.

- **Smaller, bushy form**: Smaller, multi-stemmed trees normally produce more biomass of a higher leaf: stem ratio than larger, single stemmed species.

- **Deep-rooting**: Take-up nutrients and water out of reach of root-crops.

- **Easy to establish**: Trees are easy to raise from seed either directly field-planted or in pots. Cuttings develop more rapidly but produce only lateral roots that compete more with neighboring crops.

- **Repeated coppicing and/or re-sprouting ability**: Stems and leaves grow back again and again after pruning or topping.

- **Nitrogen Fixing**: Nitrogen fixing trees are able to 'fix' atmospheric nitrogen and contribute this to the system in leaf litter fall/break-down.

- **Free from pests and diseases**: Trees should not be hosts to crop-damaging insect or fungus pests.

- **Easily controlled**: Trees that become weedy and will spread into alleys or neighboring fields are not desirable.

- **Widely adaptable and stress tolerant**: Trees should be adapted to a range of soil characteristics and tolerant of environmental diversities such as high winds and periodic drought.

- **Multipurpose**: To provide an adequate return to land and labor inputs, trees must produce a number of useful products and services.

The multipurpose tree species so far identified as being very promising for Pacific Island use are: *Calliandra calothyrsus*, *Glicidia sepium*, *Flemingia macrophylla*, and *Erythrina subumbrans*. All grow rapidly and produce lots of soil enriching 'green manure', good fuelwood, and fodder. *Calliandra* and *Gliricidia* can both produce fuelwood diameter limbs within one year. *Flemingia* and *Erythrina* usually produce smaller diameter stems early-on, but more leaf litter than the other two. On very acid soils (<pH 5), *Calliandra* does the best. *Flemingia* litter takes longer to break down which can be an advantage in the tropics where some humus build-up is desired. All have done well on both basalt and coral derived upland island soils.

Less tried but also promising are, *Albizia saman*, *Pithecellobium dulce*, *Paraserianthes falcatoria*, *Cajanuc cajan*, and some *Acacia*, *Leucaena*, and *Prosopis* spp.

*Albizia*, *Acacia*, and *Prosopis* spp. all have a tendency to become weedy on islands. *Leucaena* species are also considered weeds in most situations and are attacked by psyllid insects when pruned repeatedly as in HI systems. *Paraserianthes falcatoria* and *Cajanuc cajan* tend to die back after 3 or 4 years of repeated pruning. These species do not coppice very well in general. *Paraserianthes* is also very susceptible to wind damage.

**HEDGEROW TREE SPECIES FOR PACIFIC ISLAND UPLANDS**

*Calliandra calothyrsus* *Gliricidia sepium*

*Flemingia macrophylla* *Erythrina subumbrans*

*Albizia saman*  
*Leucaena leucocephala*

*Pithecellobium dulce*  
*Leucaena diversifolia*

*Cajanus cajan*  
*Paraserianthes falcatoria*
Wise tree species selections cannot be made without considering planting site characteristics. Species all have unique sets of tolerances and preferences for certain soil types and climates. The following site factors must be examined so that, suitable tree species are selected:

- Mean annual precipitation.
- Mean annual temperature.
- Length and frequency of yearly droughts.
- Yearly/daily minimum and maximum temps.
- Incidence of frost.
- Topography: elevation, aspect, and %slope.
- Soil pH, texture, and depth.

II SPATIAL ARRANGEMENT

Orientation: The ideal tree row would be oriented east to west, perpendicular to prevailing winds, and parallel to slope contour. This orientation provides maximum "alley" (crop) sun exposure and maximum erosion control. Obviously, this is not always possible. Tree rows should be oriented to provide the most benefit and the least competition given the particular environment. Where there is slope, it is always best to plant along contours.

'Alley' Width: The most important HI system design decision is alley width. Alley width will determine the ratio of tree products/services to crop product and the degree of competition between the root-crops and trees. If alleys are too narrow, root-crop yields will drop off dramatically as tree hedges grow. If alleys are too wide, the soil improving role of trees is reduced and long fallows will still be required. Based on tried systems, a 5 to 6 meter width is recommended.

Within row spacing: The recommended hedge consist of two lines of trees 50 cm. apart. Trees within the lines should be at 30 to 50 cm. spacings. Close spacings encourage more leaf and smaller branch production. In general HI systems of 2-row hedges and wider alleys are more productive than those of 1-row hedges and narrower alleys. With 2-row alleys, there is less tree-crop interface (competition).

Root-crop spacing: Root-crops should be planted at traditional spacings. The space between crop plants and any one tree row should be at least 0.5 m.

---

EXAMPLE HEDGEROW ROOT-CROP INTERCROPPING LAYOUT

0.5 METERS

YAMS

KUMARA

SWEET POTATO

0.5 METERS

1 METER

0.5 METERS

0.5 METERS

=>ROTATION=>

DIAGRAM ADAPTED FROM WORK OF NFTA ASSOCIATE CHARLES ROGERS, VANUATU
III. MANAGEMENT AND PRODUCT HARVESTS

Hedge Pruning: Periodic hedge pruning is necessary to prevent trees from shading-out your crop. The amount/frequency of pruning required will depend on the shade tolerance of a particular root crop at a particular stage in development. Most root-crops are very light demanding but will benefit from some shade during the first couple months of development. Shade also discourages weeds. A good rule is to maintain a hedge height equal to the distance between the hedge and nearest crop row (50cm to 1m).

Pruning frequency will also depend on the product mix desired. More frequent pruning adds more 'green manure' to the soil. Less frequent pruning will produce more fuelwood-diameter branches.

The timing of prunings is more important in tropical environments where leaf decomposition and organic matter mineralization occur rapidly. Prunings should be timed so that applied litter is releasing nutrients when the root crops are most demanding - during rapid corn development.

Crop Rotations and Fallows: Continuous cropping may be possible in some very productive HI systems where organic matter and nutrients are continually returned to the soil in large enough quantities.

It is likely though, that some fallow between the normal 3 to 4 year cropping period will be required. Two years seems to be a reasonable period. After a 2-year fallow, during which hedges are left alone, a major fuelwood harvest can be expected. Crop yields are the best indicator of the fallow requirement. Once the hedgerows are in place, the farmer should experiment with different fallow lengths to find the combination that yields the most while maintaining the site's productivity. Different sites will require different management strategies. In any situation, continued, close observation of crop performance is essential.

PRODUCTS AND SERVICES PROVIDED BY TREE HEDGEROWS

- NUTRIENT CYCLING FROM DEEPER SOIL LAYERS
- GREEN MANURE AND MULCH BENEFIT COMPANION FOOD CROPS
- MULCH AND SHADE SUPPRESS WEEDS
- FAVORABLE CONDITIONS FOR BENEFICIAL SOIL ORGANISMS
- BARRIER TO CONTROL SOIL EROSION
- BARRIER TO DRYING WINDS
- PRUNINGS FOR ANIMAL FODDER
- PRUNINGS FOR FIREWOOD AND POLES
- SUPPLY BIOLOGICALLY FIXED NITROGEN TO SYSTEM

ACKNOWLEDGEMENT

The technical guidelines offered here are based largely on information collected by the AIS Information Officer during field visits and personal interviews with project personnel. The following research projects are especially noteworthy and continue to provide useful information on this subject for all those interested:

EC/Pacific Region Agricultural Program Agroforestry Trials at USP Alafua, Apia, Western Samoa. Stephen Rogers, IRETA Research Fellow.

Plantation Training Center, Integrated Smallholder Cropping/Livestock Trials, Montmartre, Port Vila, Vanuatu. Charles Rogers, Project Manager.

GTZ/Fiji-German Forestry Project, PO Box 14041, Suva, Fiji. Martin Hornola, Chief Forestry Advisor, and Wieland Kunzel, Technical Advisor.
Managing Organic Matter: Composting and Mulching

Many farming activities interfere with or even prevent the natural processes of nutrient and organic matter cycling. Some harvesting practices remove plant material or organic matter year after year while returning none to the soil. The inevitable result is a rapid decline in soil productivity. In some cases inorganic store-bought fertilizers are then added in larger and larger quantities to sustain crop yields. In other cases, farmers must allow a soil to fallow or 'rest' for several years between relatively brief cropping periods. Both of these methods of soil maintenance are very costly, especially where land and/or cash is in short supply.

Agroforestry strategies that integrate trees with crops provide a variety of products and services depending upon species included, management techniques, etc. They do share one common objective—sustaining the soil organic matter component.

The trees in all agroforestry systems, make continuous organic matter contributions to the soil. Scattered trees in fields, windbreaks, and live-fences all shed leaves and branches. Trees in hedgerow intercropping systems are usually chosen and managed purposefully to maximize their organic matter contribution. Leaf material is frequently pruned and applied to cropping soil as green manure.

Some grasses and annual 'cover-crops' are seeded and grown seasonally in fields to provide organic matter or 'green manure'. Various Crotalaria and Sesbania species are grown in this way and then plowed into soils between cropping periods.

Organic matter management—returning organic matter to a soil as it is removed—can do wonders to increase and sustain a soil's productivity. All of the properties of a highly productive soil are dependent upon the presence of organic matter:

- **Soil fertility:** Organic matter adds plant nutrients to the soil as it breaks down. It also provides sites for nutrients to bind to, holding them in upper soil layers where plants can use them.
- **Soil structure:** The slimes and microbial gums produced by decomposing organic matter bind soil particles. The result is a stronger, granular, more permeable and workable soil.
- **Soil water holding capacity:** A soil with good structure is more permeable and porous. Water infiltrates more easily and is held in small soil pores.
- **Soil pH:** Organic matter additions reduce the pH of excessively alkaline soils. The decomposition process releases hydrogen ions, increasing soil acidity.

Without regular organic matter addition, soils become drained of essential plant nutrients and unable to absorb or retain water. As their structure is weakened, soils are much more susceptible to the forces of wind and water erosion.

All trees, regardless of how they are arranged or managed, can be regularly harvested for organic matter. This plant material can then be applied to the soil surface around crops as mulch or mixed with the soil in piles or pits to form compost.

Mulching

Mulching is the spreading of any material—green or dry on the soil surface.

**What are the benefits of mulching?**

- **Mulch controls weeds:** A good layer of mulch shades the soil and prevents weeds from germinating.
- **Mulch conserves soil moisture:** It creates a barrier against the drying effects of sun and wind.
- **Mulch fertilizes soil:** As mulch breaks down, it releases essential plant nutrients.
- **Mulch builds soil structure:** As mulch breaks down, it makes the surface soil permeable and increases its water holding capacity.
- **Mulch stops soil erosion:** It protects soil from the erosive forces of wind and water. It shields soil from heavy raindrops and slows runoff water that flows over the soil surface.
What materials can you use for mulch?
- **Plant materials:** Leaves, small branches, coconut husks and stems, and wood chips all make good mulch. Whenever possible, cut or crush materials into small pieces. Smaller sized pieces produce a more effective mulch.
- **Animal residue** such as manure. Do not use fresh/wet manure as this can burn plant roots.

How do you apply mulch?
- **Before planting:** If you want to apply mulch before planting, spread the plant material about 4 cm thick over individual rows or the entire area. Then just clear small areas for seed/seedlings and plant as usual. Do not cover newly sown seeds with mulch.
- **After planting:** If you want to mulch after planting just take care not to damage seedlings. If the plants or trees are already established, just pile mulch around the bases of trees in 1 m diameters.

Composting
Composting is the practice of mixing and piling plant and/or animal material with soil to form partially decayed, smaller particles of organic matter-or **humus**. Composting practices favor the micro-organisms that work or break organic matter down into the proteins, starches and sugars of humus. Humus contains chemical and mineral substances in forms that plants can use immediately. Humus is also the form of organic matter that most directly adds to a soil's productive properties.

What are the benefits of composting?
Composting simply speeds the organic matter breakdown process that occurs over time in nature when the same materials pile up in layers on the soil surface as mulch. Composted organic matter can be placed in direct contact with plant roots as a soil amendment or bedding material. Compost improves soil properties just as mulch does just more immediately and extensively. Compost is really just partially decomposed mulch. A soil that contains a lot of compost or organic matter is said to have a "spongy structure". Such soil resists compaction and erosion. It captures and holds water, oxygen, and essential plant nutrients.

What materials can you use for compost?
- **Plant materials:** Leaves from trees or grass, animal manures, twigs, sawdust, wood-ash, and kitchen scraps all make good compost ingredients.
- **Animal residues:** Dry or wet manure can be used for composting.

How do you make compost?
Quite simply, you make compost by throwing of organic matter-and some soil-into a big pile or pit.

Many consider composting an art and recommend special composting structures and various material layering techniques. Most recommend gathering all needed materials at once to form a complete pile. These techniques demand lots of time and labor.

You may not have enough material on-hand to build a complete pile at once. You can also create a good compost pile over time, bit by bit. Making a good compost is not that tricky but there are some simple steps that will greatly speed the whole process:

- **Add an equal ratio of green to dry material:** Add dry stems, leaves and soil to your pile in equal measure with green plant material and manure.
- **Keep compost moist:** Build your compost pile in the shade and keep it covered with large leaves, coconut fronds, or a mat. If it rains often enough you should not have to add any water. It is best to check the pile every few days to make sure it stays moist. It should not be too wet-just moist.
- **Keep compost aerated-provide oxygen:** Turn/mix your pile once a week. The microbes that work the compost need oxygen.

All of the above will speed the process of organic matter decomposition by favoring the activity of the microorganisms responsible. A compost made and maintained like this will be ready for use about 6 weeks after the last ingredients are added.

How do you use the compost?
You can use the finished compost as a potting mix, a bedding mix, or a soil amendment. If your soil is really poor, you may want to raise demanding food crops such as vegetables, in beds or pots of only compost. This is a common practice on atolls where soil is often completely lacking in organic matter. You can also add compost to existing soil or dig it into the soil surrounding a plant.

You can also just dig holes next to fruit trees and periodically throw organic matter into them. This works where soils are well drained. If too wet, these pits may lack the oxygen required by the composting microbes.
Nitrogen Fixing Trees as A Toll Soil Builders

Atoll soils form from coral reefs that grew on the tops of subsiding volcanoes during various periods—throughout the Pacific. Most of these soils are quite young in geologic terms and thus still similar in property to this coral parent material. Coralline soils are extremely nutrient deficient and highly alkaline. They are especially lacking in iron, potassium, and nitrogen. The so-called "soil" of atolls is really not soil at all since it is not made up of the usual components of soil: mineral sand, silt, and clay. Organic matter is all that really does distinguish most atoll soil from crushed coral.

Atoll farmers have always practiced mulching and composting to some degree. Most consider regular organic additions integral to any agricultural activity. Organic matter management—more on atolls than anywhere—is crucial to sustained food production. Organic matter holds nutrient ions, retains precious soil moisture, and buffers soil pH. In all soils, it builds and maintains good soil structure and provides essential plant nutrients. In atoll soil, it must also take the place of the missing clay component in providing nutrient cation exchange sites that are crucial to nutrient cycling processes.

Atoll farmers and gardeners typically make compost by piling-up rotted coconut shells/stems, household rubbish, and any green material they can find. Most simply pile this material next to a target crop or tree as a mulch. The mulch then breaks down into compost over time. Many actually make compost first-and then purposefully place it into garden trenches, holes, and tao pits as bedding material.

Although composting has always been part of the farming/gardening routine on atolls, one key ingredient is in very scarce supply—Fresh/green organic matter. As a result, mulch and compost are often spread too thinly to yield significant benefits. Compost formation is slowed drastically in piles with too high a dry: green (carbon:nitrogen) ratio of organic material.

Nitrogen-fixing trees are gaining recognition as promising atoll agroforest/garden additions and renewable sources of soil-building organic matter. Anyone who knows a bit about the unique characteristics of these trees should not find this surprising.

Why Nitrogen Fixing Trees?

Nitrogen-fixing trees are able to "fix" or take-up atmospheric nitrogen (N2) that is not available to other trees. They do this through a symbiotic relationship with certain bacteria (Rhizobium and Frankia) that form nodules in their roots. When the leaves and branches of these trees drop off, or are harvested, this nitrogen becomes available to other plants or animals in the ecosystem.

Most nitrogen fixing trees are "pioneers"—they establish easily on poor or degraded sites. These tenacious trees also grow rapidly, and produce large amounts of nitrogen-rich green foliage in some rather harsh environments.

Good mulch/compost producing nitrogen fixing trees for atolls also have the following characteristics:

- A high leaf nitrogen concentration
- A tolerance to excessive soil alkalinity
- A tolerance to excessive soil salinity
- A relatively high leaf tannin content: Many nitrogen fixing trees---such as Acacia spp.—contain tannins that slow the decomposition process. This is desirable in very humid, warm environments where the rapid break-down of organic matter prevents the build-up of a protective mulch or humus layer.
- Repeated and vigorous resprouting/regrowth after pruning: Many nitrogen fixing trees can be pruned or lopped as often as four times a year.
- Multi-purpose/multi-product: In addition to compost/fertilizer, many nitrogen fixing trees produce human-food, firewood/charcoal, pig or goat fodder, and timber or poles for construction.

Written by K.R. Dalla Rosa, Program Director for the Pacific, NFTA, 1010 Holomua Road, Paia, Hawaii 96779 USA
Establishing and Integrating Nitrogen Fixing Trees
Because land-area is so scarce on atolls, it is especially important that selected trees be easily integrated into existing systems. Depending on local needs and preferences, a variety of tree planting and maintenance schemes are possible.

Living fences and hedges protect crops from roaming animals and human foot-traffic. Trees are arranged densely or planted as fence posts.

Windbreaks are single or multiple rows of trees planted on windward field boundaries. Windbreaks slow wind, reducing physical damage to crop's and fruit trees. Placed on the windward side of atolls, they can also prevent salt-spray from reaching the interior and reduce coastal erosion.

Hedgerows are dense single or multi-row plantings of trees within fields or among fruit tree plantations. Trees are arranged to minimize competition with the associated crop and pruned regularly to add compost or 'green manure' to the farming or garden system.

Shade and support are attained quickly from fastgrowing nitrogen fixing trees. Shade provides protection from the hot, drying sun. Living, soilenriching support is quickly established for vine crops such as beans, potatoes, yams, and pepper.

Home garden plantings of nitrogen fixing trees provide soil organic matter/fertility while yielding edible fruits, leaves and flowers.

If a nitrogen fixing tree is being introduced to a site for the first time, seed or soil inoculation may be required. Seed inoculation is the process of coating seeds with the nitrogen fixing bacteria prior to planting. The inoculant is just a material that contains the bacteria. Inoculation is required when the proper bacteria is not already living in the soil where the tree will be planted. Most nitrogen fixing bacteria tolerate adverse environmental conditions such as soil alkalinity, to the same degree as the host tree. Inoculant for various nitrogen fixing tree species can be obtained from the NijTAL Center, 1000 Holomua Road, Paia, HI USA 96779.

Problems/Limitations with Nitrogen Fixing Trees
Weediness is a potential problem with nitrogen fixing trees, especially on small atolls with few native species. These trees, because of their nitrogen fixing capability, establish easily, grow rapidly, and tend produce large quantities of seed. Genetic improvement research has produced several varieties of many species such as Leucaena leucocephala. These improved varieties have less tendency to become weedy and are more compatible with crops. They are thus safer for introduction. All species introductions should be made with considerable caution.

On atolls, competition for precious groundwater is another possible problem where nitrogen fixing trees are planted into fields or fruit-tree plantations. Proper spacings and management techniques-such as periodic pruning-should reduce this problem.
Promising Nitrogen Fixing Trees for Atolls

The following nitrogen fixing trees are those that are proving themselves in harsh atoll conditions as good, renewable sources of nitrogen-rich mulch/compost material. All of these trees are tolerant to high soil pH. Those that are especially tolerant to soil salinity are noted for this. Each brief profile includes a list of outstanding characteristics and primary uses. All are easily propagated by seed and recommended seed-treatments are listed.

**Acacia auriculiformis**
- Low to medium sized tree 8 to 20 m in height
- Thornless, heavily branched, short, crooked stem
- Open, spreading crown
- Tolerates droughts of 4 to 6 months
- Tolerates poor drainage/waterlogging
- Used for fuelwood, construction
- Boil seed for 30 seconds-let soak overnight or scarify

**Albizia lebbeck**
- Moderate to large deciduous tree
- Reaches 30 m in height with enough rain
- Straight bole when grown in dense forests
- Spreading and low branching in the open
- Produces an abundance of seed, unless coppiced frequently
- Tolerates droughts up to 8 months
- Highly tolerant of salt-spray
- Shallow roots-subject to wind-throw
- Leaves and young twigs make good livestock fodder
- Wood good for construction and fuel
- Soak seed in cool water 24 hrs or scarify

**Calliandra calothyrsus**
- Multi-stemmed shrub to 6 m
- Tolerates droughts to 6 months
- Used for fuelwood, fodder (fresh), honey
- Does not tolerate waterlogging
- No treatment necessary
- Soak seed in cool water 24 hrs or scarify

**Casuarina equisetifolia**
- Tall tree to 30 m
- Conifer-like appearance
- Thrives in sea-spray zones
- Tolerates droughts to 8 months
- Not tolerant to brush fires
- Relatively short-lived-40-50 years
- Used for fuelwood, charcoal, windbreaks
- No seed treatment necessary

Source: Little, 1982
**Gliricidia sepium**
- Small, branching tree to 10 m
- Tolerates droughts to 8 months
- Tolerates saline soils
- Coppices and re-sprouts vigorously
- Used for fodder, nurse tree, live-fencing, windbreaks
- Leafless sticks root easily
- No seed treatment necessary

**Pithecellobium dulce**
- Medium, thorny tree to 15 m
- Broad-spreading with irregular branches
- Coppices vigorously
- Shallow roots—subject to wind-throw
- Used for fuelwood, honey, fodder, edible pods
- Highly tolerant of soil salinity
- Tolerant to drought
- No seed treatment necessary—or scarify

**Sesbania grandiflora**
- Medium tree to 12 m
- Tolerates droughts to 7 months
- Highly tolerant of soil salinity
- Tolerates poor drainage/waterlogging
- Susceptible to wind damage
- Used for fodder, edible flowers
- Scarify or soak seed in cool water 24 hrs

**Sesbania sesban**
- Small, shrubby tree to 6 in
- Tolerates droughts to 8 months
- Tolerates periodic flooding and waterlogging
- Regenerates rapidly after pruning
- Used for fodder, firewood, edible flowers/leaves, windbreak
- Scarify or soak seed in cool water 24 hrs

**Illustrations**


Windbreaks are single or multiple rows of trees planted to protect an area from prevailing winds. Windbreaks are planted along the windward boundaries of fields to provide a more favorable environment for crop growth. Windbreaks are also established to protect and improve the environments around homes, gardens, and villages.

Windbreaks are especially important on Pacific Islands where stiff trade winds blow throughout the year and tropical storms occur frequently. Salty maritime winds affect the most interior areas of exposed smaller islands.

Why slow the wind?

Wind can be very destructive, especially when combined with high temperatures, drought conditions, or salty sea air.

- **Wind damages crops**: Strong winds break stems, strip leaves, and tear fruit from crop plants.
- **Wind sucks moisture from plants**: When wind blows against crop plants, it dries the air immediately surrounding them. When this *boundary* air is dry, more moisture is pulled from the plant through *transpiration*. This is why plants wilt in high winds.
- **Wind sucks moisture from the soil**: Wind dries the soil surface, pulling moisture from soil pores.
- **Wind removes fertile top-soil**: Even moderate winds can remove tons of topsoil annually from fields that are exposed during cultivation and harvesting. The topsoil is the most organic and fertile soil layer.
- **Wind carries salt**: Along coastal zones and on small islands wind can deposit tons of salt per hectare annually. In soil, salt draws moisture away from plants. Deposited on some plants, salt burns leaves and kills plant tissue.
- **Wind affects the health/performance of livestock**: Animals exposed to cold or hot winds can become stressed and much less productive.

- **Wind affects human environments**: Strong winds can disrupt or damage human households. Wind-borne dust may be a human health hazard.

Because they slow the wind, windbreaks conserve plant and soil moisture, prevent crop damage, prevent soil erosion, and reduce salt-spray. They also enhance animal welfare/performance and create a more habitable environment for humans.

Windbreaks made up of well-chosen multi-purpose tree species may also provide a variety of household and marketable products including fodder, fuelwood, timber, poles, fruit, mulch/compost, spices and medicine.

**Windbreak Design**

There are a few important windbreak design considerations:

**Orientation**: Correct windbreak orientation is crucial. You should obviously plant your windbreak on the windward side of the land-area or field you want to protect. You must also plant your windbreak in lines that are perpendicular to the prevailing wind direction. This may not be so obvious. If the wind direction changes from season to season you need to decide when it is most important to provide protection. This might be when the crop is most susceptible to wind damage, when the soil is exposed, or during the most windy season. In most Pacific locations, trade winds blow from a fairly constant direction so orientation should not be difficult or risky.
• Multiple versus single row: To be most effective, your windbreak should include at least two rows of trees. This is because you want a wind barrier from the ground, up. Tall trees will protect a larger area of field, but they have high canopies and will thus leave an understory gap. Smaller trees are needed to this gap.

You can use the same range for between-row spacing. Again consider tree canopy size. Do not space the rows so closely that the larger row will shade-out the smaller row.

Always plant trees in each row so that they are in-line with gaps between trees of parallel rows. This staggering produces more effective windbreak sooner.

• Species selection: You can plant your windbreaks with a variety of species. Obviously, trees used for windbreaks should be wind-strong, and deeply rooted. The best species for windbreaks also have branching habits and relatively narrow crowns.

Choose species that are well adapted to your particular site and suited to your needs. If you need more fodder for your animals or fuelwood for your home, choose species tolerate strong winds while also yielding fodder and fuelwood. For consistency in height and ease of management, you should include only one species in each single row.

If you are able to plant a double-or multi-row windbreak, choose smaller trees for the most windward row and medium to larger trees for the next row.

The area protected will be larger if the windbreak is partially permeable rather than too dense. This is because too-dense a barrier can result in more turbulent air movement downwind. Some species make ideal windbreaks because their foliage filters rather than blocks the wind. The conifer-like foliage of *Casuarina* is one example.

• Grid design: This rather new windbreak technology is gaining popularity. Single-row windbreaks are laid out in a grid pattern on a field creating several smaller cells or squares. This technique is especially effective where the wind often shifts direction.

If you cannot sacrifice the land-area that a multirow windbreak requires, plant a single-row windbreak. A single row of trees can form a reasonable windbreak-and it is certainly better than nothing.

• Windbreak height and between windbreak spacing: For every 1 m of height, your windbreak will protect 10 m of field area. A windbreak that is 10 m high will protect a field area 100 m downwind-so a windbreak 10 m high and 100 m long will protect a one hectare field.

If you are able to plant a double-or multi-row windbreak, choose smaller trees for the most windward row and medium to larger trees for the next row.

The area protected will be larger if the windbreak is partially permeable rather than too dense. This is because too-dense a barrier can result in more turbulent air movement downwind. Some species make ideal windbreaks because their foliage filters rather than blocks the wind. The conifer-like foliage of *Casuarina* is one example.

• Grid design: This rather new windbreak technology is gaining popularity. Single-row windbreaks are laid out in a grid pattern on a field creating several smaller cells or squares. This technique is especially effective where the wind often shifts direction.

Choose species that are well adapted to your particular site and suited to your needs. If you need more fodder for your animals or fuelwood for your home, choose species tolerate strong winds while also yielding fodder and fuelwood. For consistency in height and ease of management, you should include only one species in each single row.

If you are able to plant a double-or multi-row windbreak, choose smaller trees for the most windward row and medium to larger trees for the next row.

The area protected will be larger if the windbreak is partially permeable rather than too dense. This is because too-dense a barrier can result in more turbulent air movement downwind. Some species make ideal windbreaks because their foliage filters rather than blocks the wind. The conifer-like foliage of *Casuarina* is one example.

• Grid design: This rather new windbreak technology is gaining popularity. Single-row windbreaks are laid out in a grid pattern on a field creating several smaller cells or squares. This technique is especially effective where the wind often shifts direction.
Windbreak Management
You will not necessarily have to manage your windbreak once it is established. Depending on the species you include however, you can prune, pollard, or otherwise treat trees in various rows to provide alternative products or maintain a more desirable height relative to other rows.

The management or harvesting practices you choose for each row will obviously influence the height and form of that row relative to the others. You should plan accordingly. For example, you can use shorter rows for things like fodder or fuelwood production because you will be pruning or pollarding them regularly. You can leave the taller rows alone to grow to their maximum height. You can also use the taller trees in ways that do not reduce their height-for fruit, nut production.

Management treatments can affect a tree's resistance to strong winds. Shoots that grow up from a pollarded stem, will be very susceptible breakage at the stem joint once they reach a certain size. If you pollard the most windward row of your windbreak for several years and then leave it alone to grow in height, sprouting branches will probably break in strong winds.

You can even harvest complete rows in your windbreak on a rotational basis if the trees are good timber producers. In this case, you would plant a new row to be functional at the time the mature row is harvested.

Problems/Limitations and Alternatives
Field boundary conflicts: It is unlikely that the ideal orientation for your windbreak will conform perfectly to your field boundary. If the boundary is nearly perpendicular to the prevailing wind, you can simply plant a windbreak as a form of boundary planting. If it is not, a boundary planting will not protect your crop from the wind. It may in fact, speed wind in your field because the wind may be forced along-rather than against it. The most effective windbreaks are those that stretch across boundaries and are the cooperative efforts of a number of farmers.

Loss of land: Windbreaks of two or more tree rows will take a substantial portion of your land out of crop production. Most successful windbreaks though, boost crop yields enough to compensate for this loss of area. Once your windbreak is in place, you may even be able to grow a more marketable or valuable crop/variety.

Competition with crops: Windbreaks may reduce the yield of crop plants in the area immediately next to them. This is due to competition for sunlight or water. Again, the increase in yield resulting in field interiors should compensate for this.

Pest problems: Some trees make nice homes for birds that will eat some crops-especially grains.
The following are species which have proven themselves as effective windbreak components. They are grouped by typical size at maturity. For each, common additional uses are noted.

The species in **bold** are especially tolerant to salt spray.
Species with asterisk * are more shallow rooted and may blow over in typhoons.

**Smaller trees**
- *Sesbania sesban*-green manure, animal fodder
- *Sophora tomentosa*-fuelwood, nitrogen-fixing
- *Tournefortia argentea*-fuelwood, shade

**Medium size trees**
- *Acacia auriculiformis*-fuelwood, shade
- *Acacia confusa*-shade, firewood, nitrogen-fixing
- *Acacia mangium*-fuelwood, nitrogen-fixing
- *Albizia lebeck*-timber, nitrogen-fixing
- *Azadirachta indica* (neem)-fuelwood, timber, insecticide
- *Cassia fistula*-fuelwood
- *Casuarina equisetifolia*-fuelwood, poles, nitrogen-fixing
- *Erythrina poepiggiana*-green manure, shade, nitrogen fixing
- *Erythrina variegata*-green manure, nitrogen-fixing
- *Gliricidia sepium*-green manure, animal fodder, fuelwood, nitrogen fixing
- *Intsia bijuga*-sturdy construction timber
- *Melia azedarach*-fuelwood, timber, tools, shade
- *Pinus caribaea*-timber, shade
- *Pithecellobium dulce*-fuelwood, animal fodder

**Taller trees**
- *Calophyllum inophyllum*-boat-timber, lamp-oil, shade, medicine
- *Cassia siamea*-fuelwood, small timber, animal fodder (toxic to pigs), edible leaves & flowers
- *Cordia alliodora*-timber
- *Cordia subcordata*-timber, edible seed
- *Tamarindus indica* (tamarind)-edible pods, charcoal, animal fodder, nitrogen-fixing